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TEST-FREE PERSON MEASUREMENT WITH THE RASCH SIMPLE LOGISTIC MODEL

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Test-Free Person Measurement with the Rasch Simple Logistic Model

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Rasch (1960) has proposed a simple logistic model for tests of intelligence or attainment which hypothesizes that the probability of a correct response to an item is a function of the ability of the person and the difficulty of the item. Rasch has been able to demonstrate mathematically that his model allows the separation and the independent estimation of these two parameters. Thus, in theory, given a set of calibrated items which fit his model, one may calculate ability estimates on the same scale from responses to any subset of items. This means that alternative or partial forms of a test may be scored on a common scale. Comparable scores presumably can be obtained even when the same items were not administered to all subjects, thereby making possible the individualized administration of tests in which only those items relevant to the examinee's ability level are administered. In short, the Rasch simple logistic model makes possible what Wright (1968) has characterized as test-free person measurement. If these claims are substantiated, tests developed in accordance with the Rasch model would represent a marked improvement over tests developed in accordance with classical psychometric theory.

Although introduced in 1960, this aspect of the Rasch simple logistic model has been virtually ignored. Several investigators have studied the use of the model for item calibration (Anderson, Kearney, & Everett, 1968; Brooks, 1965; Rasch, 1960; Tinsley & Dawis, 1972a, 1972b; and Wright, 1968) but the work of Wright (1968) represents the only investigation the present authors were able to find which attempts to determine whether the model leads to test-free person measurement. Wright's research is based upon the responses of 976 beginning law students to 48 reading comprehension items on the Law School Admission Test. Wright divided the original 48-item test into two sub-tests, one containing the 24 easiest items, the other containing the 24 hardest items. For each subject, Wright calculated his raw score and his Rasch ability estimate on the two tests. He then calculated the difference between the two raw scores and the difference between the two ability estimates, and compared the distribution of the differences for the two types of scores. Wright points out that the distribution of differences for raw scores, with a mean of 6.78 and a standard deviation of 3.30 is almost entirely above zero (see Table 1). On the other hand, the distribution of differences in Rasch ability estimates, with a mean of .061 and a standard deviation of .749, is centered around zero. Wright (1968) concludes that the alternative Rasch ability estimates seem to be in agreement.

Insert Table 1 about here.

Wright goes a step further with the Rasch ability estimates. For each individual, he divides the difference between the two ability estimates by the measurement error of this difference. This produces what Wright calls the distribution of standardized differences with a mean of .003 and a standard deviation of 1.014. Wright concludes from these data that the only variation observed in ability estimates is of the same magnitude as that expected from the standard error of measurement in the test, and that these data support the claim that the Rasch simple logistic model allows the measurement of a person with any set of calibrated items.

Two problems with this investigation must be noted. First, the results were biased in favor of the Rasch model when Wright chose to summarize the difference between scores on the two tests in terms of the mean. Because the raw scores are all positive, differences in raw scores will all be positive. The Rasch ability estimates are logarithms, however, half of which are negative. Approximately half the differences in logarithmic ability estimates will be negative, with the result that the mean difference in logarithmic ability will be close to zero. Use of the absolute value of the differences would have avoided this problem. The results were further biased in favor of the Rasch model when Wright utilized the standardized difference in the logarithmic ability estimates without doing so for the difference in raw scores. Computation of the mean standardized absolute difference for both types of scores would have been preferable.

The assertion, then, that the Rasch simple logistic model allows test-free person measurement remains largely unsubstantiated. Clearly, this question deserves considerable attention. The purpose of this research was to investigate this claim.

Method

Instruments. Four analogy tests, combined into two test booklets, were utilized in this study. The first test booklet contained a 60-item word analogy test followed by a 40-item symbol analogy test. The second test booklet contained a 60-word number analogy test followed by a 50-item picture analogy test. All items were of the multiple choice type with five response alternatives and with the blank in the item stems distributed among the four positions. All tests were introduced by one standard page of test instructions.

Subjects. Two samples of subjects were employed in this study. College students enrolled in an introductory psychology class at the University of Minnesota during the Fall of 1970 constituted the first sample. All were volunteers (obtained through the subject pool of the Department of Psychology) who were participating in the research to gain additional points toward their course grade. Some students completed only one of the test booklets while others completed both of them. High school students enrolled in two suburban Twin Cities high schools constituted the second sample. Each student completed one test booklet. In both high schools, the test booklets were completed by students in the classes of those teachers who volunteered to participate in the study.

Because the test forms were designed to be self-explanatory, subjects were simply given the test, instructed to read the directions, and to complete the test. The test administrator was always available, however, to answer any questions. No time limits for completion of the test were set but students in the high schools were allowed only one fifty-minute class period in which to complete the test.

Analysis. The procedure for such an investigation need not be complicated. First a sample of subjects must be administered two tests of the same ability, composed of items which have been calibrated on a common scale. Then, scores on these two tests must be converted to ability estimates on a common scale. These ability estimates should be approximately the same, with errors of measurement accounting for all the differences. Four such comparisons were made in this study, one each with word, picture, number and symbol analogies. In each case, the sample of high school students and college students was combined. Next, each test was divided into two subtests. The subdivision of the word picture, and symbol analogy tests was straightforward. First, the items in the total test were arranged in the order of their easiness. Then they were divided into two subtests with one subtest containing the hard items, the other the easy items. Because there were so many easy items in the number analogy test, this procedure was amended slightly. After the number analogies had been arranged in order of their easiness, the 25 easiest items were assigned to one subtest. Then items 26 through 35 were assigned to the second subtest. Items 36 through 40 were then assigned to the first subtest and items 41 through 60 were placed in the second subtest. This procedure was necessary because the ceiling on a subtest composed of the thirty easiest number analogies was so low that many subjects would have received perfect scores, necessitating their elimination from the study.

After the tests had been divided into subtests, the raw score, percentile rank, and Rasch ability estimate of each subject was computed for the two subtests. These item characteristics were computed using a program developed by Wright and Panchapakesan (1969,1970) and modified by Bart, Lele, and Rosse (1970) for use on the University of Minnesota CDC 6600 computer. Finally, the product-moment correlation and the mean and standard deviation of the absolute difference between the scores on the two subtests were computed for the raw scores, percentile ranks, and Rasch ability estimates. Support for the hypotheses that the ability estimates are invariant with respect to the easiness of the items in the test would be indicated if the correlation between ability estimates on the two tests approaches unity and the distribution of the absolute differences between ability estimates on the two tests centers around zero.

In each case, the sample for a given test consisted of those college and high school students who had completed the test, minus those whose score on the total test was lower than the r index recommended by Panchapakesan (1969), and minus those who received a perfect or a zero score on either of the the subtests. The r index is an index suggested for the identification of subjects with scores so low that guessing may have been a factor in determining their ability estimates. Thus, only those subjects for whom guessing was not a factor were included in this analysis. Table 2 indicates the number of examinees excluded from this study and the number remaining.

Insert Table 2 about here.

Results

The invariance of raw scores, percentile ranks, and Rasch ability estimates was investigated. If raw scores differ only by a constant associated with the difference in the difficulty of the test, the correlation between the two sets of raw scores should approach unity and the mean of the distribution of absolute differences should be the constant. But if this is true, conversion of the raw scores to percentile ranks, separately for each subtest, should be an effective method for equating subtest scores. Accordingly, the correlation between the two sets of percentile ranks should also approach unity, but the mean of the distribution of absolute differences in the subtest percentile rank scores should approach zero. In practice, however, the above result is seldom observed. Scores differ by a variable rather than a constant amount. Measurement by the Rasch model supposedly avoids this problem. Since the items in the subtests were calibrated on a common scale, the Rasch ability estimates from the two subtests should be on a common scale. This means that there should be no difference in the scores of the two subtests. The correlation between scores on the two subtests should approach unity and the mean of the distribution of absolute differences in scores should approach zero.

Table 3 gives the correlations between the scores on the four types of subtests. The highest correlations were observed between scores on the word analogy subtests, with raw scores and percentile ranks correlating .68 and Rasch ability estimates correlating .67. Intermediate correlations were observed for the picture and number analogy subtests. For the picture analogies, raw scores correlated .47, percentile ranks correlated .50, and Rasch ability estimates correlated .48; the corresponding correlations for number analogies were .47, .51, and .51. The lowest correlations occured for symbol analogies. Raw scores correlated .27, percentile ranks correlated .30, and Rasch ability estimates correlated .27.

Insert Table 3 about here

Table 4 indicates the mean and standard deviation of the distribution of absolute differences in subtest scores for each of the four tests. The mean difference in raw scores ranged from 9.25 for symbol analogies to 12.56 for number analogies with the mean varying between 3.0 and 3.5 standard deviations above zero. The mean differences in percentile ranks were .18 for word analogies, .22 for number and picture analogies, and .27 for symbol analogies, and varied between 1.2 and 1.3 standard deviations above zero. The mean differences in Rasch ability estimates were .55 and .57 for word and picture analogies, .72 and .73 for number and symbol analogies, and, like the mean differences for percentile ranks, vary between 1.2 and 1.3 standard deviations above zero.

Insert Table 4 about here.

Discussion

One of the most promising features of the Rasch model is that it would make possible the individualization of measurement. Once a pool of items calibrated on a common scale has been developed, individuals need complete only those items appropriate to their ability level and their scores can be converted to ability estimates on a common scale. This means that the scores of the individuals can be compared even if the tests they completed do not have one single item in common. It was with this feature of the Rasch model that this research was concerned.

This research investigated the hypotheses that raw scores, percentile ranks and Rasch ability estimates are invariant with respect to the items used in measurement. The data indicate that there is little difference among the three ability measures; all three are dependent upon the items used in measurement. However, this finding is misleading--a reflection of the inadequacy of the research design. In the first place, it is illogical to assume that tests which do not fit the Rasch model will still have the characteristics attributed to it. Only one of the eight subtests used in this research had a Rasch maximum likelihood probability greater than .05. The probability of the easy picture subtest was .03 and the probability of the hard symbol subtest was .44. The maximum likelihood of the remaining six subtests was less than .001. There is no reason, therefore, to expect that results based on these tests will possess the properties of the Rasch model.

Another problem with this research design concerns the method of administering the test questions. The goal of the Rasch model is to measure the individual as accurately as possible. The precision of the measurement depends on the number of items used in the measurement and the appropriateness of the items for the ability of the examinee (Panchapakesan, 1969). If the use of the Rasch model is to lead to more precise measurement, the standardized method of item presentation in which each examinee answers every question must be abandoned. Take, for example, the case of a low ability subject. Many of the items on the easy subtest were no doubt appropriate for measuring his ability. It is even possible that his ability was rather precisely estimated in this subtest. In contrast, most of the questions on the hard subtest were inappropriate for this examinee. Each of the questions gave very little information about his ability and the resulting ability extimate was based upon very little information. Consequently, the two ability estimates would have very little chance of agreeing.

If the research design for this study is inappropriate, how is it that Wright (1968) achieved satisfactory results using essentially the same design? It has already been suggested that Wright analyzed his data incorrectly. Wright reported the mean and standard deviation of the distribution of differences, where the mean and standard deviation of the absolute differences would have been more appropriate. Table 5 presents the means and standard deviations of the distributions of signed differences for the data reported in this study. The results represent Wright's (1968) method of analysis and can be compared with those presented in Table 4. The results for word, picture, and symbol analogies, when looked at in this manner, compare favorably with those reported by Wright (see Table 1.) Wright (1968, pp. 95-96) interprets his results as indicating that the Rasch simple logistic model yields item-free person measurement. It has been shown, however, that these results are artifacts of the method of analysis employed.

Insert Table 5 about here.

The research design, then, was inappropriate for testing the hypothesis that Rasch ability estimates are invariant with respect to the items used in measurement. A successful test of this hypothesis requires a procedure for the individualized administration of items. Subtests could be constituted from odd-numbered vs. even-numbered items, after ordering all items according to easiness. A stringest test of the hypothesis could still be obtained by estimating an individual's ability on two subtests, one consisting of largely inappropriate items (e.g., very easy items), the other consisting of items appropriate to the ability of the examinee. In both cases, testing would continue until a specified precision of measurement was achieved. If the hypothesis is supported, the two ability estimates would be identical within the limits of error allowed by the precision of measurement.

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Table 1

Mean, Standard Deviation of Differences in Scores
on Easy and Hard Tests
(N = 976)

Ability Estimate	Mean	Standard Deviation
Raw scores	6.78	3.30
Rasch	.061	.749

Table 2

Sample Size

Analogy Test	Initial Sample	Reasons for Deletion: Low Total Score	Reasons for Deletion: Perfect Subtest Score	Final Sample
Word	949	62	22	865
Picture	612	14	8	590
Number	626	36	10	580
Symbol	938	83	21	834

Table 3

Coorelation of Subtest Scores

Ability Estimate	Analogy Test			
	Word	Picture	Number	Symbol
Raw Score	.68	.47	.47	.27
Percentile Rank	.68	.50	.51	.30
Rasch	.67	.48	.51	.27

Table 4

Mean, Standard Deviation of Absolute Differences in Subtest Scores

Ability Estimate	Analogy Test			
	Word	Picture	Number	Symbol
Raw Scores	10.14± 3.35	10.43±2.97	12.56±3.70	9.25±2.92
Percentile Rank	.18± .15	.22± .18	.22± .18	.27± .21
Rasch	.55± .42	.57± .47	.72± .57	.73± .56

Table 5

Mean, Standard Deviation of Signed Differences in Subtest Scores

Ability Estimate	Analogy Test: Word	Picture	Number	Symbol
Raw Scores	10.14±3.36	10.42±3.00	12.55±3.76	9.24±2.95
Percentile Rank	.007±.238	.003±.288	.017±.286	-.008±.343
Rasch	.047±.696	.094±.733	.196±.901	.038±.916

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